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Heuristic Based Decision Support System for Choice of Alternative Routes in the Large-Scale Transportation Transit System on the Base of Petri Net Model

Igor Kabashkin*

Transport and Telecommunication Institute, Lomonosova 1, LV-1019 Riga, Latvia

Abstract

The term Decision Support System (DSS) are much appreciated in highly complex environments where problems or tasks have varying degrees of structuration. Computer-based DSS to support decision making abound in elaborate functionality but they are often difficult to use effectively in real business environment, and are therefore often not used at all. In the paper the DSS for choice alternative of routes in the large-scale transportation transit system embedding the heuristic approach and integrating simulation was developed. Practical realization of DSS simulation on the base of Petri Net model is proposed. Transport system as complex and safety-critical is one of the main application of various DSS. Process of E-net model design for choice alternative of routes in the large-scale transportation transit system includes the heuristic decision-making construction according to general scheme, formal method for transformation of heuristic decision-making construction into the Petri Net model and base set of modelling elements for above-mentioned transformation procedure and software tools. The detailed rules for design of Petri Net model make it easy to transform the initial heuristic selection criteria in formalized procedures of model construction.

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* Corresponding author

E-mail address: Igor.Kabashkin@gmail.lv

1. Introduction

The term Decision Support System (DSS) is widely used for any kind of system, which provides valuable information necessary to support decision-making process. These systems are much appreciated in highly complex environments where problems or tasks have varying degrees of structuration; some of them are unstructured or semi-structured. Transport system as complex and safety-critical is one of the main application of various DSS. There are a lot of DSS models for transport applications, for example, for rail (Zhang Xi, Jian Liu 2005; Katsman et al. 2011; Rui Zhao et al. 2013), ocean (Kenneth L. Stott, Jr. Burnie W. Douglas 1981), urban (Yatskiv, Yurshevich 2015; Jesus Gonzalez-Feliu, Josep-Maria Salanova Grau 2015; Ossowski et al. 2005) transportation systems and for multimodal transport networks (Zhihong Jin, Qi Xu 2012; Eren Özceyla 2010; Cathy Macharis et al. 2008; Kabashkin, Lučina 2015).

Usually, in freight transport DSS for the each multimodal freight transportation the decision-maker can offer several alternatives for cargo delivery determined by different routes or/and modes. Search for the best solution or finding a set of good alternatives in realization of multimodal freight transportation should be based on a set of the initial data, considering logistic principles, and be done using modern mathematical methods and computer engineering. A lot of them propose the multiple-criteria approach for transportation system evaluation, but for the alternative, they include these criteria into generalized cost criteria.

Above mentioned computer-based systems to support decision making abound in elaborate functionality but they are often difficult to use effectively in real business environment, and are therefore often not used at all. Designers of DSS applications are appealing to the reliability of the model to inform their expectations about future interactions with the world. Such expectations point to the mental, or cognitive, modelling that is characteristic of human consciousness this internal, personal model making seems far removed from programming.

Theoretical studies on rational decision making, notably that in the context of probability theory and decision theory, have been accompanied by empirical research on whether human behavior complies with the theory. It has been rather convincingly demonstrated in numerous empirical studies that human judgment and decision making is based on intuitive strategies as opposed to theoretical rules. These intuitive strategies, referred to as judgmental heuristics in the context of decision making, help decision makers in reducing the cognitive load. Formal discussion of the most important research results along with experimental data can be found in (Marek J. Druzdzel, Roger R. Flynn 2002; Rasmequan et al. 2000).

In the paper the DSS for choice alternative of routes in the large-scale transportation transit system embedding the heuristic approach and also integrating simulation was developed. A detailed description of the developed simulation model is beyond the scope of this paper.

2. General approach for heuristic based decision support in transport transit system

The large scale transportation transit system is presented by directed finite graph which is an ordered pair $D = (V, A)$, where $V = \{v_i\}$, $i = \overline{1, n}$ is set of finite vertices (railway stations, ports, border points and logistics centres) and $A = \{a_j\}$, $j = \overline{1, m}$ is set of finite arcs (transport lines between different gates).

Under these conditions, decision-making can be used by systems with customized decision models. The main idea behind this approach is automatic generation of a graphical decision model on a per-case basis in an interactive effort between the DSS and the decision maker. The DSS has domain expertise in a certain area and plays the role of a decision analyst. During this interaction, the program creates a customized influence diagram, which is later used for generating advice. The main motivation for this approach is the premise that every decision is unique and needs to be looked at individually; an influence diagram needs to be tailored to individual needs (Holtzman 1989).

One of the general approaches for heuristic taxonomy of cargo owner's preferences in transport systems with customized decision models was proposed in (Kabashkin 2003). The framework for heuristic decision-making sets out the factors influencing the transit sector from users' point of view in the order of their priority (Fig. 1): $D = \{F_i\}$, $i = \overline{1, 4}$, where F_i – factor of influence: F_1 – geographical plane, F_2 – economical plane, F_3 – institutional/political plane, F_4 – infrastructure and technology plane.

If there are $j = \overline{1, n}$ alternative routes in the large-scale transportation transit system, the decision making process in this case can be described by heuristic procedure given in Fig. 2.

From the point of view of decision making a model and its variables represent the following three components: a measure of preferences over decision objectives, available decision options, and a measure of uncertainty over variables influencing the decision and the outcomes.

Preference is widely viewed as the most important concept in decision making. Outcomes of a decision process are not all equally attractive and it is crucial for a decision maker to examine these outcomes in terms of their desirability.

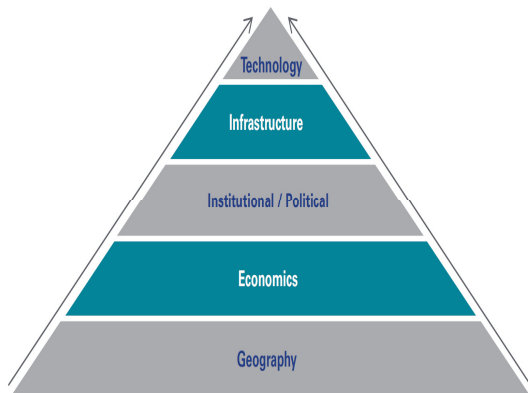


Fig. 1. Heuristic taxonomy of cargo owner's preferences in transportation.

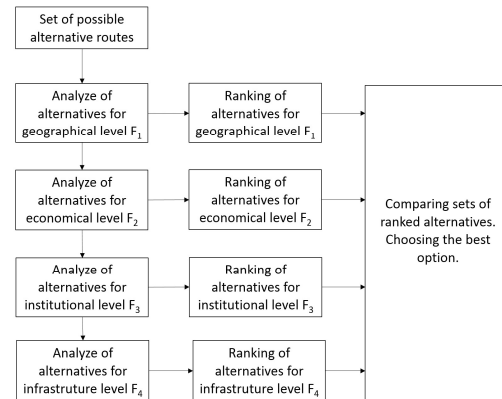


Fig. 2. Heuristic procedure for choice of alternative routes in the large-scale transportation transit system.

The second component of decision problems is available decision options. Often these options can be enumerated, but sometimes they are continuous values of specified policy variables. Listing the available decision options is an important element of model structuring.

The third element of decision models is uncertainty. Uncertainty is one of the most inherent and most prevalent properties of knowledge, originating from incompleteness of information, imprecision, and model approximations made for the sake of simplicity.

Decision making under uncertainty can be viewed as a deliberation: determining what action should be taken that will maximize the expected gain.

In the paper, the approach to modeling heuristic based decision support systems was performed using the simulation on the base of Petri Nets with customized decision procedure shown in the Fig. 2.

3. Definitions and notations

The complex system is given by the structure of elements and connections. The restrictions on basis of elements are not imposed. The dynamic model of system's operation should provide opportunity to account of initiating events distribution in system and dynamics of their evaluation in time.

For decision of delivered problem we shall use the properties of Evaluation Petri Nets (E-Net) (Nutt 1972), formally defined as follows:

$$E = (P, T, I, Q, M),$$

where $P = \{S\}$ – is a finite nonempty set of simple positions; $T \neq \emptyset$ – is a finite nonempty set of transitions; $I: T \rightarrow P$ – input and $Q: P \rightarrow T$ – output functions describing input and output arcs of each transition; $M: P \rightarrow \{0,1\}$ – a marking of the graph (the tokens presence in the positions).

Any transition $t \in T$ can be described as $t = (\sigma, \tau, \pi)$, where σ – is a type of an elementary network of transition; τ – is a procedure of delay; π – is a procedure of transformation.

We shall determine a class of elementary networks by a set $\sigma = \{T, F\}$, offered in (Nutt 1972), where T – simple transition, F – duplication (Fig. 3). In addition we upgrade this set by elementary network $= \{G\}$, where G is generator of tokens.

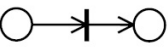
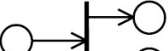
Class of Elementary Networks	Graph	Marking of the Graph
T - Simple Transition		$(1,0) \rightarrow (0,1)$
F - Multiplication		$(1,0,0) \rightarrow (0,1,1)$

Fig. 3. Class of elementary networks of Petri Net.

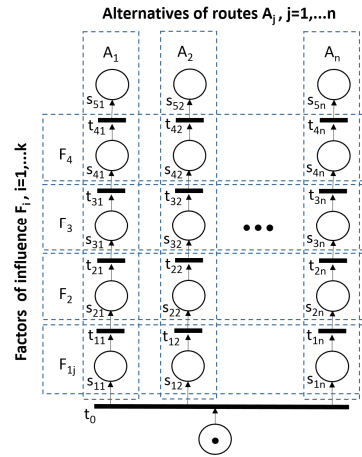


Fig. 4. Petri Net model.

4. Model construction

Process of E-net model design for choice alternative routes in the large-scale transportation transit system includes four main components:

1. The heuristic decision-making construction according to general scheme (Fig. 2).
2. Formal method for transformation of heuristic decision-making construction into the Petri Net model.
3. Base set of modelling elements for above-mentioned transformation procedure.
4. Software tools for simulation experiment.

We shall build the dynamic model of system operation based on the general scheme (Fig. 2) with set of elements (Fig. 3) to formalize the transformation of the general decision-making procedure to E-net (Fig. 4). We shall interpret positions of E-net as condition of process, and transitions – as events, determined the change of condition. For design of E-net model we shall use the next rules.

1. The start of modelling iteration of choice alternative routes in the large-scale transportation transit system is displayed by elementary network $\sigma = \{G, F\}$. The transition t_0 , generates the initial event of decision-making modelling for routes alternatives of cargo transportation $A_j, j = \overline{1, n}$.
2. The logic functions for choice n alternative routes in the large-scale transportation transit system with k factors of influence in E-net is displayed by the T -type elementary network. The transitions $t_{ij}, i = \overline{1, k}; j = \overline{1, n}$ define choice alternative j at the level i of influence factor F_i .
3. The initial marking of the model. In the initial state of the model the token are present in the first positions of primary event generator, and are absent in all other positions.
4. The process of one modelling iteration is completed after filling the markers in the end positions $s_{5j}, (j = \overline{1, n})$ of the E-net.
5. Priority in the selection of transportation routes is ranked on degree of decrease of total transit time of the marker position corresponding to an alternative route $\tau_i = \sum_{i=1}^4 \tau_{ij}, (j = \overline{1, n})$.
6. The time delay of transitions τ_{ij} corresponds to the integral parameter β_{ij} preferences of a route choice at the appropriate level F_{ij} .

7. For geographical plan F_1 the integral parameter β_{1j} is proportional to total time of transportation t_j using i route: $\beta_{1j} = \alpha_1 t_j$, $(j = \overline{1, k})$. In this case $\tau_{1j} = \beta_{1j}$.
8. For economical plane F_2 the integral parameter β_{2j} is proportional total cost of transportation c_j , $(j = \overline{1, n})$ using j route: $\beta_{2j} = \alpha_2 c_j$, $(j = \overline{1, n})$.
9. For political/institutional plane F_3 the integral parameter β_{3j} is proportional reliability component r_j of logistics performance indicator (LPI) (Nutt 1972): $\beta_{3j} = \alpha_3 r_j$, $(j = \overline{1, n})$.
10. For infrastructure and technological plane F_4 the integral parameter β_{4j} is proportional infrastructure and logistics component λ_j of logistics performance indicator (LPI) (Nutt 1972): $\beta_{4j} = \alpha_4 r_j$, $(j = \overline{1, n})$.
11. The time delay of transitions τ_{ij} , $(i = \overline{2, 4}, j = \overline{1, n})$ can be described as $\tau_{ij} = -\frac{\ln(1 - \beta_{ij})}{\mu_{ij}}$, where μ_{ij} is expert

coefficient that can be defined, for example, according to AHP (Analytic Hierarchy Process), shown in (Kabashkin, Lučina 2015).

This base set of modelling elements permits to formalize transformation of heuristic decision-making process to E-net and essentially to simplify construction of DSS dynamic empirical based models for choice alternative of routes in the large-scale transportation transit systems.

Further investigation of the obtained E-net can be carried out with the assistance of simulation tools and special software (The Logistics...).

5. Conclusions

In the paper, heuristic based decision support system for choice of alternative routes in the large-scale transportation transit system is described. Practical realization of DSS simulation on the base of Petri Net model is proposed.

Process of E-net model design for choice alternative of routes in the large-scale transportation transit system includes the next main components: the heuristic decision-making construction according to general heuristic scheme, formal method for transformation of heuristic decision-making construction into the Petri Net model, base set of modelling elements for above-mentioned transformation procedure and software tools. The detailed rules for design of Petri Net model make it easy to transform the initial heuristic selection criteria in formalized procedures of model construction.

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